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Effect of fin and electrodes on electro-hydrodynamic enhanced heat transfer in enclosures

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ABSTRACT

In this work, enhancement of heat transfer in partially open finned enclosures with single fin and multiple fins was investigated experimentally. Five faces of the enclosure were insulated thermally and electrically; while one face was copper finned plate with an aperture located at its opposite face. Various parameters were considered like supplied current, electrode arrangement, number of fins, and different types of corona discharge. It was concluded that the heat transfer is enhanced while the supplied current is increased. Moreover, higher number of fins can lead to more enhancement of the ratio of heat transfer caused by electrohydrodynamic (EHD) technique. Finally, it was observed that the best location for electrodes is in front of the fins.

1. Introduction

In electrohydrodynamic (EHD) improvement technique, a large electric field can be used to increase the heat transfer in a dielectric fluid continuum by inducing a secondary flow. This secondary flow may reduce the thickness of the thermal boundary layer which leads to reduction of convective heat transfer resistance. The momentum exchange between the imposed electric field and the molecules in the dielectric fluid is responsible for the deterioration of this layer. This influence causes reducing of the thickness of the thermal boundary layer and decaying the convective thermal resistance; by which, the heat transfer is augmented.

Yonggang et al. [1] studied the effect of the ionic wind on the heat transfer rate from a heated vertical flat plate and have concluded that the convective heat transfer coefficients increase by several times with the help of the ionic wind. Bhattacharyya and Peterson [2] examined the influence of the corona wind on the augmentation of the natural convection heat transfer from a vertical copper plate. They investigated the effects of varying a series of parameters coupled with a range of electrode voltages and its polarity. They have concluded that electric field strength had a direct and significant influence on the enhancement scale, whereas polarity change of the applied field did not produce much significant influence on the enhancement ratio. Grassi et al. [3] examined the heat transfer enhancement on the upper surface of a horizontal heated plate in a pool by employing an electrohydrodynamically induced impinging liquid flow in a point-plane geometry and managed to augment heat transfer coefficients more than 200% by varying the high voltage and the point-to-plane spacing.

Some numerical modeling were developed to study the effect of imposing the electric field in the absence of the external force flow inside two dimensional cavities [4–6]. Using computational fluid dynamic, the effect of electrohydrodynamic on heat transfer within an external force flow was studied by Kasayapanand [7,8]. An experimental research was carried out to investigate the EHD enhanced heat transfer in a vertical annulus by Grassi [9]. They managed to obtain local heat transfer improvement by inserting appropriate points on the inner surface of the annulus which generally acted as the positive electrode, while the surrounding pipe was grounded.

Enhanced heat transfer techniques are classified into two main categories: active and passive methods. However, it is more advantageous to implement a combination of both methods to augment the heat transfer. For this purpose, we used EHD (an active method) in a fin attached enclosure (passive technique) in the present study. Several numerical researches are reported by Kasayapanand [10–12] which show the effect of the imposing electric field on the partially open or closed finned enclosures. In this paper, contrary to other similar works which applied computational fluid dynamics (CFD), we employed experimental investigation to study heat transfer enhancement [13]. Three different finned enclosures including single fin and multiple fins (3 and 7 fins) were constructed and used for the experiments. Both the positive and negative coronas were considered in this study. One of the shortcomings of the numerical methods is that they cannot predict the breakdown or spark over voltage correctly. A corona discharge is an electrical discharge brought on by the ionization of a fluid surrounding a conductor that is electrically energized. The discharge will occur when the strength (potential gradient) of the electric field around the

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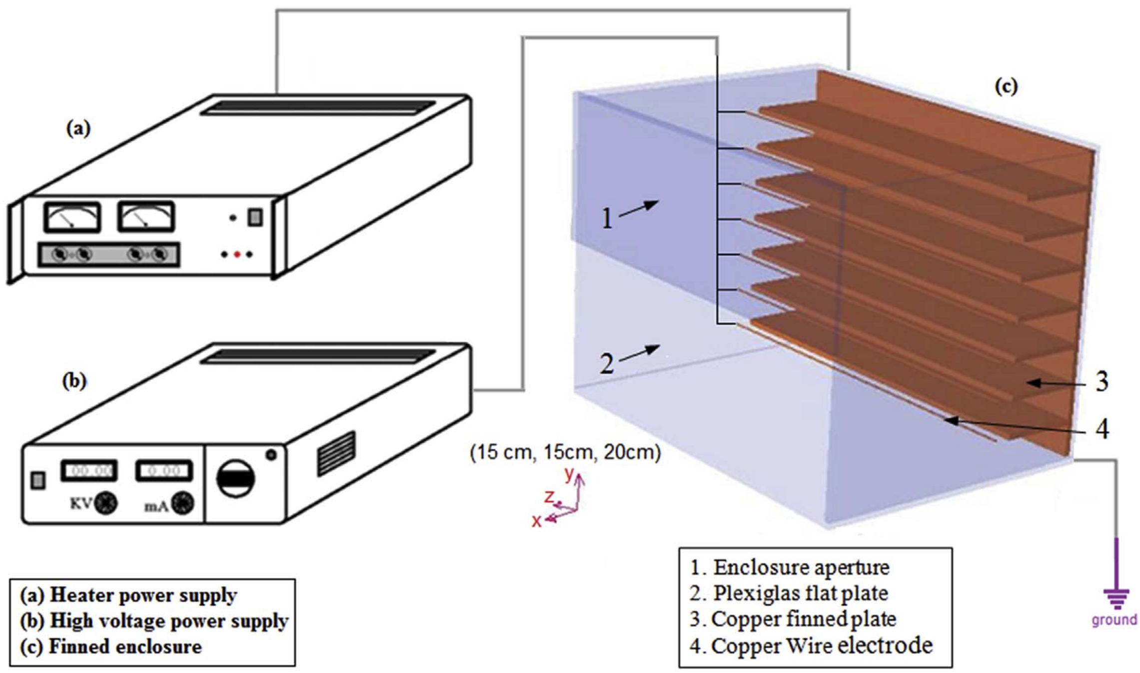

Fig. 1. Schematic diagram of the experimental setup.

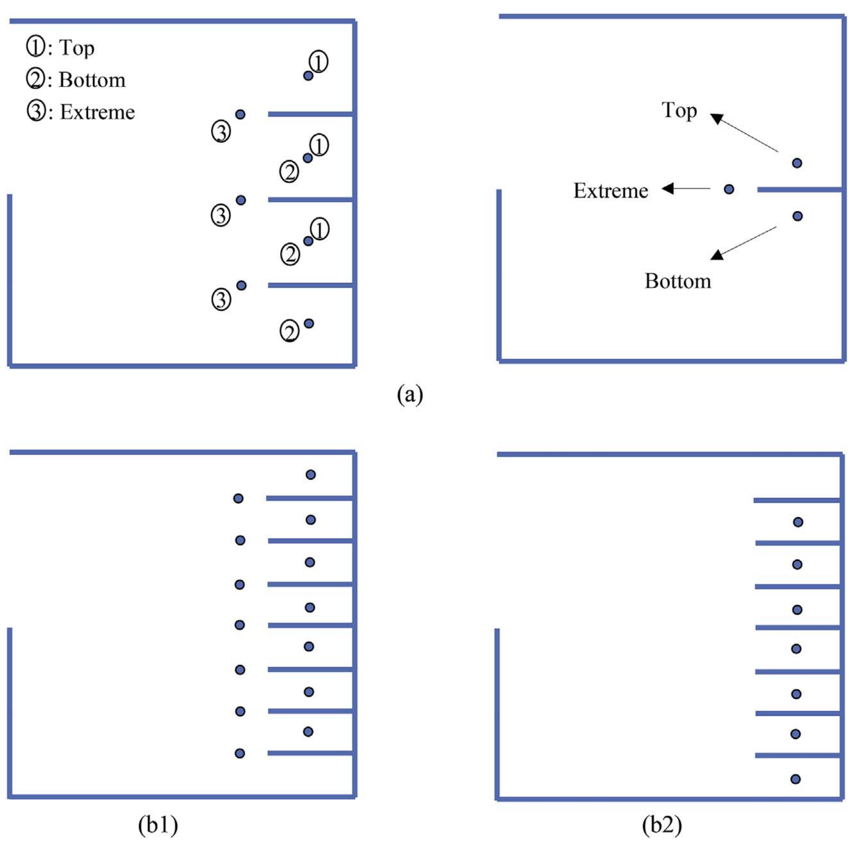

Fig. 2. The schematic diagram of electrodes position, (a) top, bottom and extreme for single&3-fins models, (b1) top and extreme, (b2) bottom for 7-fins model.

conductor is high enough to form a conductive region, but not high enough to cause electrical break-down or arcing to nearby objects. Breakdown voltage or spark over voltage is the voltage at which an insulator, e.g. air, "breaks down" and begins to pass current. The spark over voltage in the air depends on many experimental conditions such as electrodes geometry, their distance, and humidity of the air. In all cases, voltages range from zero to before the breakdown occur, were examined. Coronas may be positive or negative. This is determined by the polarity of the voltage on the highly curved electrode. If the curved electrode is positive with respect to the flat electrode, it has a positive corona, if it is negative, it has a negative corona. Using a DC high voltage between the finned enclosures induces an ionic or electric wind inside the enclosure. This induced ionic or electric wind increases the convection near the finned surface. Recently, the application of open